Journal of Environmental Sciences, 2010; Vol. 39, No. 4 : 465-481

THE USE OF THE WASTAGE CRUMB RUBBER IN ROADS CONSTRUCTION

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ABSTRACT

The use of waste byproducts in lieu of virgin materials, for instance, would relieve some of the burden associated with disposal and may provide an inexpensive and advantageous construction product. Moreover, the escalating cost of materials and energy and the lack of resources available have motivated highway engineers to explore new alternatives in building roads and rehabilitating the existing ones. The present study was targeted towards studying the effect of addition of crumb rubber on the physical properties of bitumen as well as the properties of asphalt mixes like stability, flow and tensile strengths. Furthermore, evaluation of the cycle cost of a rubberized pavement section and to carryout the economic feasibility study of its use.

To achieve such targets, four different ratios of crumb rubber were added by weight to the normal bitumen viz., 2%, 4%, 6% and 8%. Four different tests were conducted on both normal and rubberized bitumen. The conducted tests were penetration, flash point, softening point, and ductility. In addition, the elastic recovery also determined through the ductility test. Marshal and indirect tensile strength tests were also conducted on rubberized asphalt mixes as well as control one at three different temperatures viz., 20^{o}C, 50^{o} and 70^{o}. It was observed that penetration has decreased with the increase in crumb rubber ratio. While, softening point, ductility and elastic recovery have increased. The flash point increased with the addition of crumb rubber but it shows constant value with all variable ratios of crumb rubber. The rubberized asphalt mixtures show increase of the stability and tensile strength with the increase of crumb rubber ratio till certain limit and after that decreased. However, flow did not show a trend to be realized. It has been concluded that high temperatures for rubberized asphalt mixes revealed lower stability and tensile strengths.

Key Words : *Waste materials, Crumb rubber, Rubberized Asphalt, Life cycle cost.*

INTRODUCTION

Problems associated with the environmentally safe and efficient disposal of waste materials continue to grow. The cost of disposing of waste materials continues to increase while the types of wastes accepted at municipal solid waste landfills is becoming more and more restricted. One answer to all of these problems lies in the ability of society to develop beneficial uses for this waste.

The highway construction industry can effectively use large quantities of diverse materials. From a highway engineering perspective, recovered materials should be used in such a manner that the expected performance of the pavement will not be compromised. Waste and by-product materials, however, differ vastly in their types and properties and, as a result, in the highway applications for which they may be suited. Furthermore, although, good amount of research has been conducted on the use of waste materials in the highways construction industry, the mechanical and physical properties of such modified materials with waste ones required more clarifications. Therefore, there is a need for investigation of the use of waste materials like crumb rubber in the highway construction industry especially the physical and mechanical properties of such composite materials i.e, natural and waste materials such as rubberized bitumen and rubberized asphalt mixtures as well. On the other hand, from the economic point of view this process should be revised and highlighted.

For this concern, this paper studies the effect of addition of crumb rubber on the physical and mechanical properties of bitumen. Not only that but also, the effect of addition of crumb rubber on the properties of asphalt mixes like stability, flow and tensile strengths was also evaluated. The evaluation also includes the effect of variation of temperatures on the properties of rubberized asphalt mixes as well as the economic feasibility study of its use.

Literature Review :

There are many waste materials used in highway construction, such as blast furnace slag, steel slag, coal ash byproducts, including fly ash, bottom ash/ boiler slag, and flue gas desulphurization (FGD) waste, glass, sewage sludge ash, roofing shingle wastes, and rubber tires. All of these materials are creating many environmental problems, especially rubber tires. For instant, it was reported that approximately 280 million tires are discarded each year by American motorists, approximately one tire for every person in the United States, Anderton, 1992. The first trial to incorporate tire rubbers in asphalt pavements was on the 1950s. Since then, many trials were adopted however, the widespread use of this material was limited based on its experimental status and patent restrictions. All trials were hoping to capture the flexible nature of rubber in a longer lasting paving surface, Heitzman, 1992. The task was difficult and early asphalt-rubber formulas provided little or no benefit, the result was a modified asphalt pavement that cost more and had a shorter service life than conventional asphalt Later extensive research was completed in 1992 through the Construction Productivity Advancement Research Program sponsored by the Army Corps of Engineers and private industry where specifications were developed for crumb-rubber modified asphalt, Hanson, 2004. Partha, 2003 illustrated the various benefits of using rubberized asphalts such as reduction of reflective cracking in asphalt overlays, reduction in maintenance costs and improvement the resistance to rutting in new pavement. Not only that, but also it increases pavement life, improves skid resistance and decreases noise levels. However, the main objection to rubberized asphalt is the high initial costs as reported by Hicks et. al, 1999.

MATERIAL SELECTION

Bitumen :

In the present study, 60/70 -grade supplied by Kuwait National Petroleum Company (K.N.P.C) was used for the experimental work. Physical properties of the bitumen are given in Table 1.

Aggregates :

In the present study, for preparation of bituminous mixes, either with rubberized bitumen or with normal bitumen, Three different sizes of aggregates were used according to the Kuwaiti Code of Practice. The used aggregates are uncoated Olivine Gabbros which were imported from Al- Fujairah from United Arab Emirates (U.A.E). The first used gradation represents coarse aggregate of maximum particle size of 3/4 inches (CA-3/4). On the other hand, a gradation for fine aggregates of maximum particle size of 3/8 inches (FA-3/8) is also adopted. However, the third gradation represents a crushed sand material (CS). Figure1 shows the gradation curves of all adopted materials. Routine tests were conducted on a the selected aggregates in order to find out their physical properties. Table 2 shows the different physical properties of the selected aggregates as resulted from such routine tests.

Table 1 : Physical Properties of Bitumen.

Test	Test Method	Test Result
Penetration (0.01mm, 5sec, 25°c, 100gm)	ASTM - 97	65
Softening Point (ºC)	ASTM D36 - 06	56
Ductility (cm)	ASTM D113 - 07	100
Flash Point (ºC)	ASTM D92 - 05	145

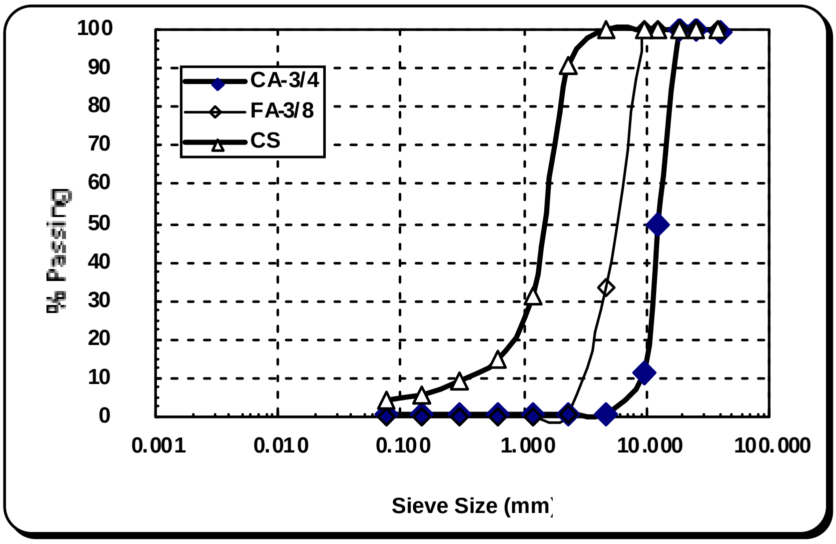

Figure 1 : Gradation Curves for Crushed Aggregate(3/4) , Fine Aggregate (3/8) and Crushed Sand.

Table 2 : Physical Properties of Aggregates.

Property	Aggregate Size	
	CA- 3/4	FA- 3/8
Flakiness Index (%)	14.4	15.5
Impact Value (%)	-	7.8
Elongation Index (%)	20.7	17.4
10 % Fine Value (KN) (Dry Agg.)	165.9	229.9
Unit Weight (Kg / m3)	1485.5	1535
Los Angeles Abrasion %	26.2	25.7
Soundness (%)	11	10.17
Relative Density (OVEN DRY BASIS)	2.92	2.79
Apparent Relative Density	2.93	2.92
Water Absorption (% OF DRY MASS)	0.13	1.42

Natural Sand :

The natural sand used in the present study was procured from Al-abdaly area in the north of Kuwait. Routine tests were conducted on the procured sand in order to find out its gradation and physical properties which shown in Table 3.

Table 3 : Physical Properties of Natural Sand.

Property	Value
Relative Density (Oven Dry Basis)	2.61
Relative Density (SSD Basis)	2.62
Apparent Relative Density	2.64
Water Absorption (% of Dry Mass)	0.54

Mineral Filler :

In the present study, the filler required for preparation of the bituminous mixes is a lime powder produced from National Industrial Company in Kuwait. Its gradation is given through Figure 2.

Crumb Rubber :

The crumb rubber used in the present study is prepared from scrape tires; the grinding machine was used to convert the scrape tires into rubber particles (ships) and rubber powder (crumb rubber). The used crumb rubber in this research is produced locally by Alzahem Industrial factory at Shuwaikh area in Kuwait. The used crumb rubber is free from steel, fibers and any foreign containments in the rubber tire. The rubber was grinding according to standard sieves to be compared with sand by weight percent. The gradation of rubber particles is shown in Figure 2.

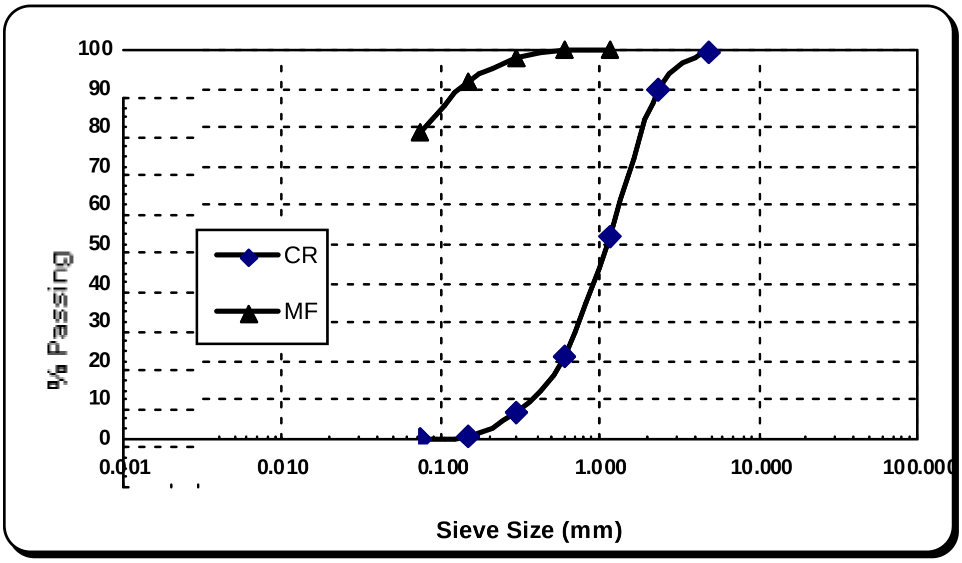

Figure 2 : Gradation Curves for Crumb Rubber (CR) and Mineral Filler (MF).

Blending of Bitumen and Crumb Rubber :

The present study was targeted to investigate the variation of crumb rubber (CR) ratio in the binder of the asphalt mixtures (bitumen). Therefore, four different percentages of CR (by weight of the bitumen sample) were added viz; 2%, 4%, 6% and 8% were added to the neat bitumen to have variation in the CR ratios.

For preparation of the crumb rubber blends, firstly, bitumen was heated to a temperature of 150°c and then crumb rubber was added to the bitumen. After that, this mix was put in the oven for one hour at 150°c. The next step was leaving the asphalt rubberized to be cold for 40 minutes and then putting in water bath for 30 minutes. The final mix is a rubberized bitumen which is ready to be used for asphalt mixes. The following section will emphasize the different tests conducted on both neat and rubberized bitumen to find out the variation in the properties of bitumen as a binder for asphalt mixes.

TESTS ON BITUMEN :

Penetration Test :

Penetration test is the most commonly adopted test on bitumen to grade the material in terms of its hardness. Depending upon the climatic condition, bitumen of different penetration grades are used. In warmer regions lower penetration grades are preferred and in colder regions bitumen with higher penetration value is used. In this test, bitumen is softened to a pouring consistency between 80°C to 110°C. The sample material is thoroughly stirred to make it homogeneous and free from air bubbles. The sample material then poured into the container to a depth at least 15 mm more than the expected penetration. The sample containers are allowed to cool in atmosphere for one hour. Then it is placed in temperature controlled water bath at a temperature of 25°C for a period of one hour. A standard needle is then allowed to penetrate into the surface for 5 seconds under the correct loading. This is done by means of an instrument known as penetrometer. This test is standardized by ASTM D946 - 82 (Reapproved 2005).

Softening Point Test :

The softening point of a bituminous binder is the temperature at which a disc of the binder softens sufficiently to allow a steel ball, initially placed on the surface, to fall through the disc and a prescribed distance. It is usually determined by Ring and Ball test. Softening point essentially is a temperature at which binders have an equal viscosity. Bitumen with higher softening point may be preferred in warmer place. In this test, two brass rings are filled with hot bitumen and allowed to cool in air for 30 minutes. The excess bitumen is trimmed and the rings are placed in supports. At this time, the temperature of water is kept at 5°C for 15 minutes. The temperature of water is raised at uniform rate of 5° per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate buy sinking of balls.

Ductility Test :

Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at

27^{O}C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BS. The same test can be presented in another way by using the concept of elastic recovery.

The elastic recovery of modified bitumen is evaluated by comparing recovery of thread after conditioning the specimen at specified temperature (25^{O}C) and the specimen is elongated up to 10 cm deformation in a ductility machine. Immediately the test specimen is cut into two halves at the mid point using a pair of scissors. Then the specimen is kept in the water bath in an undisturbed condition for one hour at specified temperature. After one hour time period, move the elongated half of the test specimen backs into the position so that the two pieces of modified bitumen just touch. The length of the recombined specimen is recorded as X and the percent elastic recovery is calculated by Equation 1.

$$\text{Elastic Recovery} = [(10-X)/10]*100 \qquad (1)$$

Flash Point Test :

The flash point test is a test that contains a volatile distillate. The test determine the temperature at which it begins to give off ignitable vapor. The principal purpose of flash-point testing is to determine maximum safe mixing and applying temperatures. The test was conducted for both control and rubberized samples.

TESTS ON ASPHALT MIXES :

All contents of asphalt mixture i.e, aggregates, sand and bitumen/modified bitumen were blended to gather under heating and stirring them to achieve the limits of the General Specification for Kuwait Motorway / Expressway system. This is for preparation of specimens for both Marshall and indirect tensile tests.

Marshall Strength Test :

Marshal method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus. Specimens were prepared in asphalt laboratory using a mould of 63.5 mm height and 101.6 mm diameter and 75 blows were given at both sides of specimen. The specimen putted in the oven at a temperature of 150^{O}C for 30 minutes for dissolving some of the fine rubber in to the asphalt. And then it taken out of the oven and putting in the mould then the mould was placed in compaction device and 75 blows were applied to the specimen with compaction hammer for each side . After that the specimen was lifted stabilize for 10 to 20 minutes in the mould, and then the specimen was extracted from the mould by using a hydraulic jack system. Then the specimens leaved to cold for 24 hours and then the specimens were brought to specified temperature by placing in water bath at three different temperatures, 20^{O}C, 50^{O}C and 70^{O}C. This is to study the effect of temperature on rubberized mixes. The height was measured and recorded for each specimen.

On the other hand, the inside surface of the testing head was cleaned and guide rods were lubricated with a thin film of oil so that the upper test head would slide smoothly over them. The proving ring was used to measure the applied load and the dial indicator was firmly fixed and set to zero for the No-Load position. The specimen was removed from water bath and placed in the lower portion of breaking head then the upper portion of breaking head was placed on specimen and the assembly was positioned in testing machine. The flow meter then placed over longer guide rod and verified to be zero on dial. The testing load was applied to specimens at a constant rate of 50.8 mm per minute, until maximum load (failure) is noted on micrometer dial. The load in (Kg) and it's defined as the Marshall Stability value. The deformation or strains that occur to the specimens during loading to maximum value and measured by the flow - meter was reported as the Marshall Flow value in unit of (1/100) inch.

Indirect Tensile Test :

The indirect tensile strength is the maximum strength resistance in (kg/cm^2) which the standard test specimen will develop at a specified test temperature when subject to load by standardized procedure. Test specimens prepared as in Marshall test were immersed in water bath at the specified temperature (20^{o}C, 50^{o}C, 70^{o}C) for 30 to 40 minutes before testing. The plate of the testing head was cleaned and the proving ring was used to measure the applied load and the two dial indicator were firmly fixed and set to zero for the No - Load position. The testing load was applied to specimens at a constant rate of 50.8 mm per minute, until the failure occurred. The point of failure is defined by the maximum load reading obtained. The load in kilo Newton required to produce the failure of the specimen at the specified temperature was recorded. The lateral (diagonal) deformation that occurred to the specimen during loading to the maximum value was measured by the two dial gauges. The measured load value at failure (P) in kilo Newton and the thickness of specimen (h) in cm were used to calculate the indirect tensile strength value (St) by using Equation 2.

$$S_T = \frac{4P}{\pi D h} \qquad \text{.................... (2)}$$

Where:

ST = Tensile strength in Kg/cm^2.

P = Total load at failure in Kg.

h = Height of specimen in cm

D = Diameter of specimen in cm.

RESULTS ANALYSIS AND DISCUSSIONS

Penetration Test Results :

The results of the conducted penetration tests on both normal and rubberized bitumen revealed that the penetration value of bitumen decreases with the addition of crumb rubber. This is valid to the extent that it has decreased from 65 for normal bitumen to 62,60,59 and 58 with addition of 2%, 4%, 6% and 8% of crumb rubber respectively. Figure 3 also assured that since it shows a diagram comparing the resulting penetration value with added different ratios of crumb rubber. It should be reported that the decrease in penetration value should be controlled since low values of penetration is not desirable in the field. Therefore, the addition of crumb rubber to bitumen with respect to penetration should be minimized.

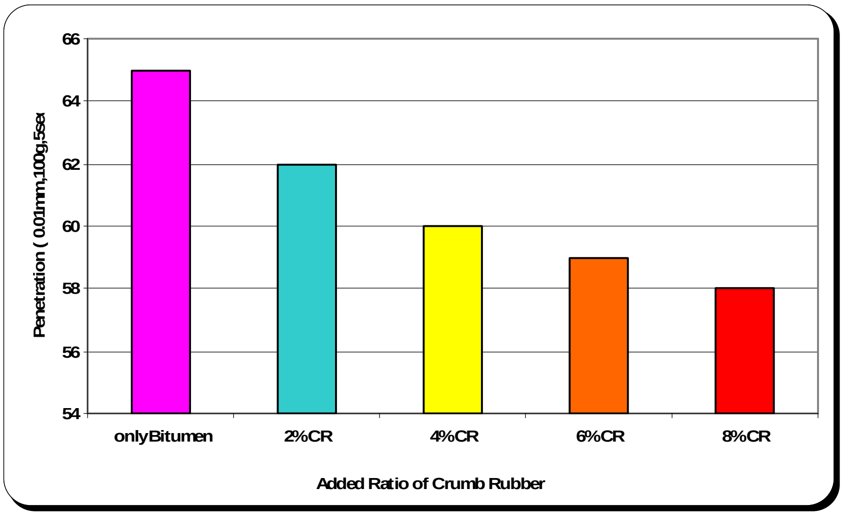

Figure 3 : Penetration values at 25°C with different added ratios of crumb rubber.

Softening Point Test Results

Based upon the tests conducted on both normal and rubberized bitumen for determination the softening point, it was observed that there is a consistent increase in softening point with the addition of crumb rubber. It has increased by 5 to 9°C with adding 2% to 8% of crumb rubber. This is can help in estimation the optimum ratio for adding crumb rubber to control the pavement temperature. It is known that pavement temperature seldom goes beyond 50 to 60°C (maximum expected temperature of local weather). So, if the added ratio increases the flash point to a degree beyond that limit, it will not be desired as it is not in a real conditions. The shown diagram in Figure 4 highlights such consistent increase in flash point with increase in the added crumb rubber ratio compared with normal bitumen.

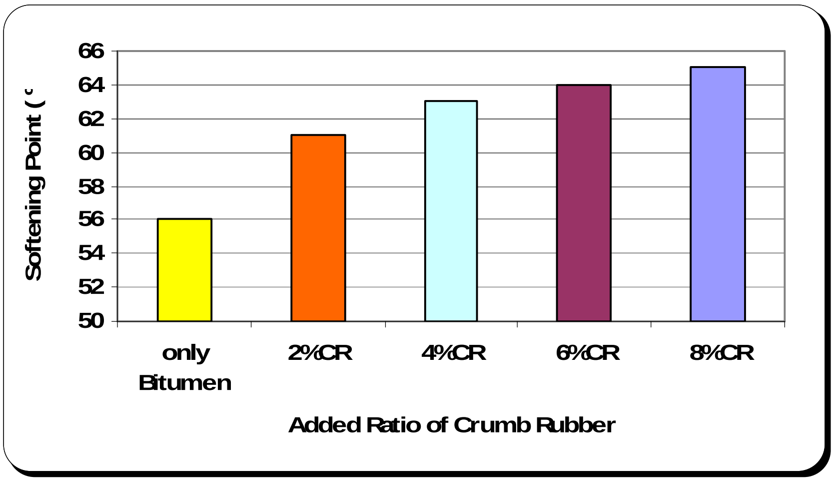

Figure 4 : Variation of Softening points of Bitumen with different added ratios of crumb rubber.

Ductility and Elastic Recovery

The conducted ductility tests revealed an increase in the ductility of modified bitumen with the increase of the added ratio of crumb rubber. For example, it has increased by 6 cm with 2% addition of crumb rubber. Furthermore, the increase was 11cm with 6% of crumb rubber. Figure 5 presents such trend. An important view should be emphasized that it is expected for more added ratios of crumb rubber, ductility will drastically decreased. This is expecting due to the fact that stretching cannot be thinner than certain limit. For the determined elastic recovery values, almost the same trend has been obtained. The addition of crumb rubber modified the elastic recovery to 50%, 60%, 75% and 80% for added ratios of 2%, 4%, 6% and 8% respectively. This is expressed diagrammatically in Figure 6. It should be reported that improvement is comparatively significant.

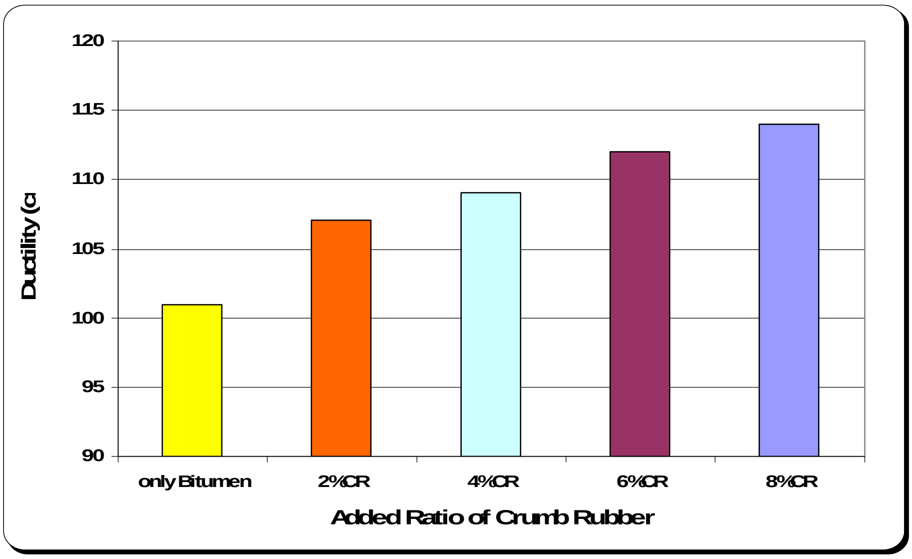

Figure 5 : Variation of Ductility of Bitumen (cm) at 27 °C with different added ratios of crumb rubber.

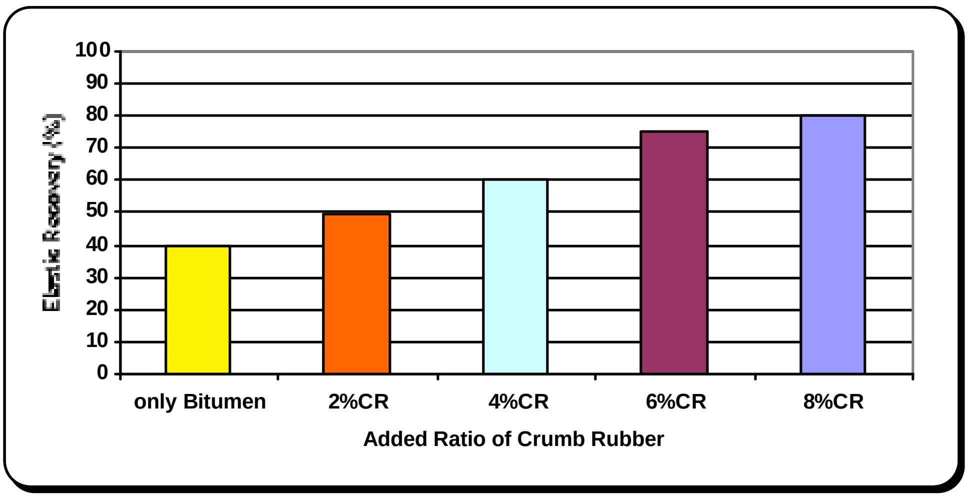

Figure 6 : Elastic Recovery Values (%) with different added ratios of crumb rubber.

Flash Point Test Results

In view of the results of flash point tests on both normal and rubberized bitumen samples. The revealed results show an unusual trend. The temperature at which the bitumen begins to give off ignitable vapor (flash point) is the same for all added ratios of crumb rubber. Firstly, it has drastically increased from 145°C to 204°C and the same value obtained with more added ratios of crumb rubber. This is may be interpreted due to that once the rubberized bitumen reaches to the flash point, then more ratios of crumb rubber will be useless as the sample already starts to be flashed. This means it has already reveal the maximum safe mixing and applying temperature. This is introduced through Figure 7.

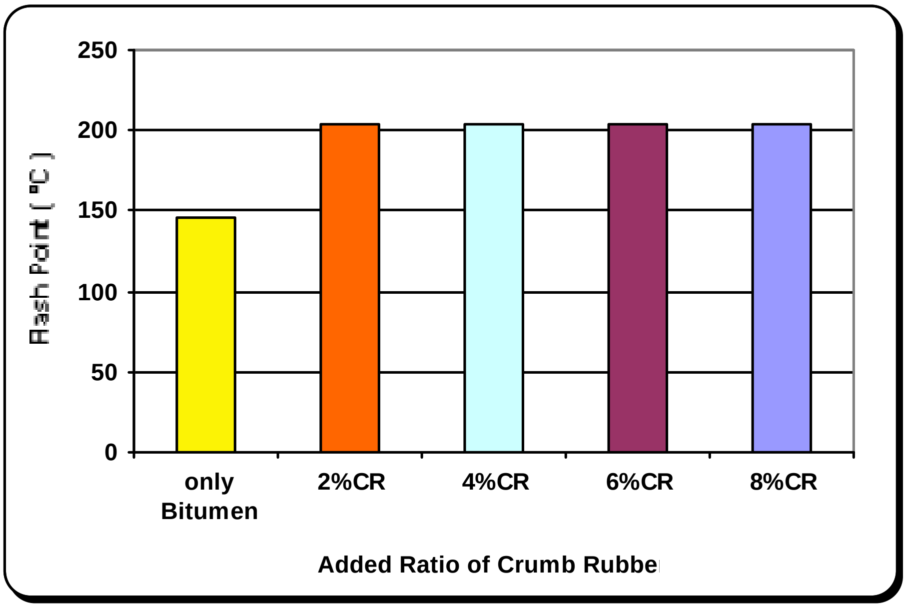

Figure 7 : Flash Points (°C) with different added ratios of crumb rubber.

Marshal Stability, Flow Values and Voids in Mixes

It has been recognized that marshal stability is a measure of structural strength of a bituminous mixes. The results of marshal tests conducted for determination the effect of addition crumb rubber to the normal bitumen show a considerable increase in the stability values. This increase continues up to crumb rubber concentration of 6% by weight after that it starts decreasing as shown in Figure 8. The increase in stability values is significant since it is ranging from 50% to 80% rather than normal bitumen. This leads to more durability over the design life of the pavement.

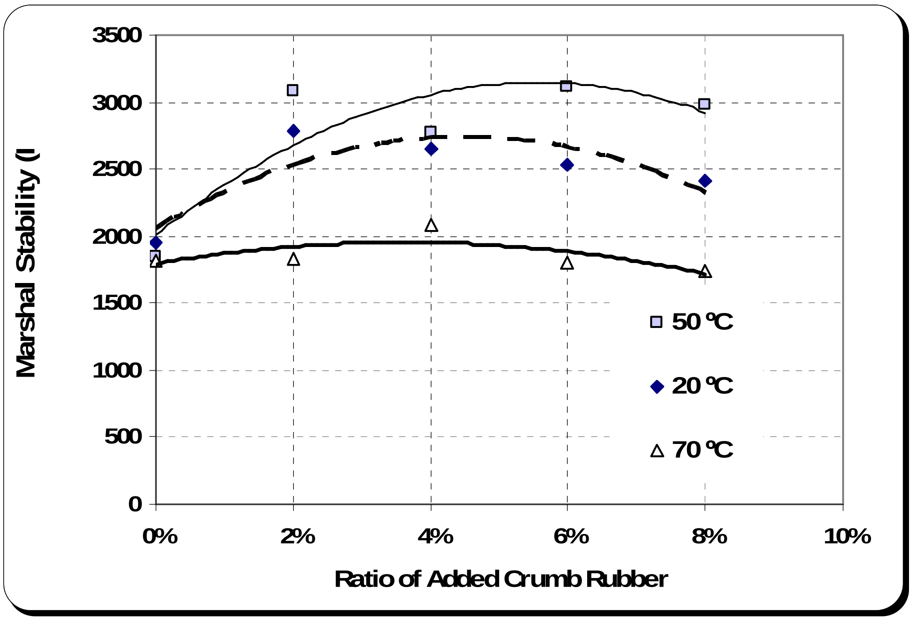

Figure 8 : Stability Values with different added ratios of crumb rubber at Different Temperatures.

In view of the effect of temperature on stability values, it is clear that there is no definite trend. The highest values of stability obtained at 50ºC. At the same time, 2ºC temperature exhibited higher values of stability rather than 70ºC. However, in general it can be concluded that higher temperatures is not desirable with rubberized bitumen/mixes since heating the rubber particles decrease the whole stability of the mix. For this issue, it may be concluded that rubberized bitumen may be recommended for cold weathers.

The flow value denotes the maximum deformation of the mix without failure. As it may be seen through Table 4, there is no definite trend for flow values. Sometimes increases with the increase in added crumb rubber ratio till certain ration and starts after that to decrease. Oppositely, sometimes it starts decreasing and after that increases. This is depending upon the test temperatures.

Table 4 : Flow Values (mm) at Different Added Ratios of Crumb Rubber At Different Temperatures.

Added CR Ratio	20 ºC	50 ºC	70 ºC
Bitumen Only	8.66	10.12	9
2%	11.69	10.83	11.52
4%	8.69	12.31	11.87
6%	11.08	11.99	12.22
8%	9.59	11.34	11.01

It should be reported that the obtained flow values also sometimes go below and up the specification limits. In general, it should be emphasized that very high flow values are more detrimental for mixes than low flow values, provided the ductility of the bitumen at low temperatures is not very low.

Tensile Strength :

So far as indirect tensile strength tests results are required, it is important to mention that a similar trend to that of the stability values is also obtained. The tensile strength increases with the increase of the added ratio of crumb rubber till certain ratio and then decreased. However, the ratio at which this decrease starting is variable depending on the test temperature.

For example, at 50^oC, the maximum tensile strength obtained at 6% of added crumb rubber. However, it was 4% for temperatures 20 and 70^oC. It should be noted that the improvement in tensile strength with the addition of crumb rubber to bitumen in asphalt mixes is ranging from 40 to 60% rather than normal bitumen. However, the effect of temperature should be considered. Figure 9 highlights such trend between tensile strength as well as the added ratio of crumb rubber to normal bitumen.

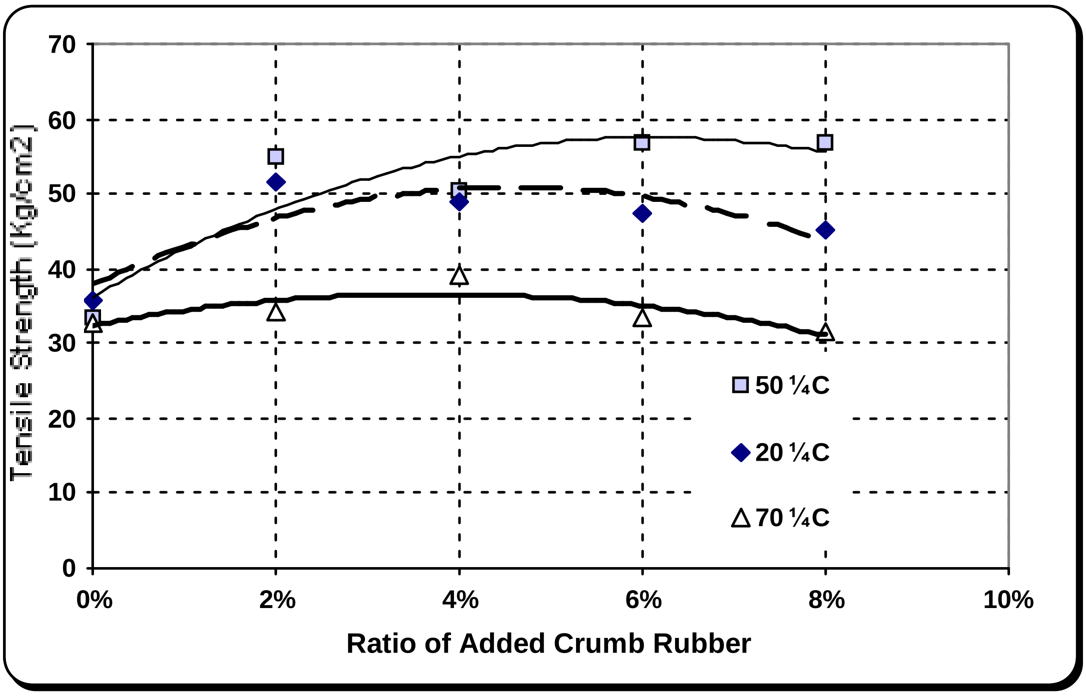

Figure 9 : Tensile Strengths with different added ratios of crumb rubber at Different Temperatures.

ECONOMIC ANALYSIS

Generally, the purpose of the economic evaluation is to get information on the basis of which investment decisions can be made. The economical evaluation must take into consideration the initial construction costs, maintenance costs and also the operating costs of the vehicles using the pavement. The estimation of vehicle operating costs entails complicated calculations under a range of conditions and comparing all costs and benefits over the analysis period. The maintenance costs for pavements are not uniform over an analysis period, but are paid out at different specified periods during the life of the pavement.

The purpose of maintaining a pavement surface is to increase its serviceability and bring the serviceability to a point that is nearly the same as that after initial construction, (Yoder and Witczak, 1975). So, the major maintenance is defined as resurfacing of the pavement surface or reconstruction that brings it to its original as-constructed condition. The construction of pavement may be in stages or in one stage. For one stage construction, only regular routine maintenance is applied however, for stage construction both types of maintenance must be applied. The initial cost of construction of a pavement will increase due to the additional cost of bitumen modifiers like crumb rubber. For this concern, the life cycle cost is worked out for 1 Kilometer section of 7.0 m wide road. The Schedule of Rates (SOR) for Ministry of Public Works in Kuwait was followed to carry out the economic analysis. The adopted section for the analysis is composed of:

1- The top 500 mm of the subgrade soil.
2- Water bound macadam (WBM) for base course (15cm).
3- Primer coat with bitumen (80/100) over top surface of the base course.
4- Tack coat with bitumen (80/100) over primed surface.
5- Bituminous concrete (B.C) with Tack coat with bitumen (80/100) over primed surface (15cm).

The initial construction cost of the proposed design section including construction costs can be estimated based upon the SOR adopted from the Ministry of public works as presented in Table 5.

Table 5 : Initial Construction Cost of Different layers without Rubberized Bitumen.

Layer	Area (m^2)	Thickness	Quantity (m^3)	Rate (K. D.)	Cost (K. D.)
Subgrade (50cm)	7000	0.5	3500	1.0	3500
Base (15cm)	7000	0.15	1050	10	10500
Primer Coat (over the surface of base)	7000	-	7000	0.9	6300
Tack Coat (over the primed surface)	7000	-	7000	0.9	6300
BC (15cm) on three layers (5 cm each)	7000	-	-	12	84000
Total Cost (K. D.)					110600

If the ratio of 6% crumb rubber is assumed to be added to the bitumen in the mixture by weight. Base upon marshal density, the square meter of the asphalt surface layer may cost 1.0K.D. Therefore, the additional cost due to the addition of the rubber materials required = 7000 K.D. (Approx. = 6 % extra cost).

So, the total cost of the rubberized section = 117600 K.D. Since, both stability and tensile strengths are exhibits considerable increase due to the addition of rubber, this leads to many benefits such as:

-The pavement service life may be increased.

-The required overlays may not required.

These benefits could be quantified in terms of cost wise as follows:

-More service life with little increase in the initial construction costs (12%).

-No maintenance costs required for more overlays.

An important environmental contribution is related to the use of the waste rubber materials with in turn consider as a solid waste requires extra costs for safe removal and also for handling and processing.

SUMMARY AND CONCLUSIONS

The significance of addition of crumb rubber with certain ratio to the normal bitumen was evaluated. Not only that but also properties of rubberized asphalt mixes were also investigated. For this issue, five different tests were conducted on both control and rubberized bitumen. Marshal and indirect tensile strength tests were also performed for both control and rubberized mixes at three different temperatures viz, 20°C, 50° and 70°. The following conclusions are drawn from this study:

1- Penetration has decreased with the increase in crumb rubber ratio. Such decrease should be controlled since low values of penetration is not desirable in the field.

2- Flash point has increased consistently with the increase of crumb rubber ratio. So, the increases limit should be controlled as it is not desired as pavement temperature seldom goes beyond 50 to 60°C.

3- There is an increase in the ductility of modified bitumen with the increase of the added ratio of crumb rubber.

4- Flash point has drastically increased from 145°C to 204°C with the addition of 2% crumb rubber. However, this value was kept constant with more increase in the added crumb rubber ratio.

5- Stability of rubberized asphalt mixes increased up to 50% with the increase of rubber ratio. However, it is starting decreasing after certain limit. But in view of the effect of temperature on stability values, it was revealed no definite trend.

6- High temperatures for rubberized asphalt mixes exhibit lower values of both stability as well tensile strength.

7- Flow values of rubberized asphalt mixes did not show definite trend.

8- Tensile strength of rubberized asphalt mixes was almost revealed similar trend to the stability.

9- The economic evaluation revealed that only 6% may be considered as extra costs of the initial construction costs of pavement costs. However, the benefits due to such extra cost may be in terms of increase of service life or reduction in the maintenance costs.

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Received on 21 / 2 / 2010

الملخص العربى

إسـتخدام مخلفـات إطـارات المركبـات فى إنشـا ء الطـــرق

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من المعروف أن صناعة وإنشاء الطرق يمكن أن تستوعب كميات كبيرة من المخلفات الصلبة حيث أن إستخدام مثل تلك المواد بديلاً عن المواد الخام المستخرجة من المصادر الطبيعية يعد إسهاماً بالغاً فى تحسين البيئة وكذلك فى توفير المصادر الطبيعية حتى لاتنضب. ومن المؤكد أن ندرة تلك المصادر فى بعض المناطق وكذلك إرتفاع تكلفتها ومصادر الطاقة اللازمة لاستخراجها وتصنيعها قد دفع المشتغلين فى مجال هندسة الطرق إلى البحث عن مواد بديلة ولكن بشرط أن تؤدى إلى طرق عالية الجودة والكفاءة مثل تلك الناتجة عن المواد الطبيعية.

وفى هذا الصدد يحتوى هذا البحث على نتائج دراسة معملية لبحث مدى الاستفادة من إضافة مسحوق مخلفات الإطارات المطاطية على الخواص الطبيعية والميكانيكية للخلطات الأسلفتية، كما إشتمل البحث أيضاً على طريقة مبسطة لحساب تكلفة إستخدام مخلفات الإطارات المطاطية فى الخلطات الأسفلتية.

تهدف الدراسة بصفة أساسية لتحقيق الأهداف الآتية :

- دراسة تأثير إضافة مخلفات إطارات المركبات على الخواص الطبيعية والميكانيكية للأسفلت.
- دراسة تأثير إضافة مخلفات الإطارات المطاطية على خصائص الخلطات الأسفلتية مثل الثبات والانسياب ومقامة الشد.
- دراسة تأثير اختلاف درجات الحرارة على خصائص الخلطات الأسفلتية المحسنة باستخدام مخلفات الإطارات المطاطية.
- تقدير التكلفة الاقتصادية لقطاع الرصف المحسن به الخلطة الأسفلتية باستخدام مخلفات الإطارات المطاطية، وتقييم ذلك بالمقارنة مع القطاع الغير محسن.

ولتحقيق أهداف البحث فقد تم تنفيذ برنامج معملى تحديد خصائص ومواصفات المواد المستخدمة مثل البيتومين العادى ومسحوق مخلفات الإطارات المطاطية والركام المستخدم فى الخلطات الأسفلتية، وكذلك إجراء بعض الاختبارات على كل من البيتومين العادى والبيتومين المحسن مثل إختبار الغرز ودرجة الوميض ودرجة التطرية والممطولية وكذلك أيضاً بعض الاختبارات على الخلطات الأسفلتية العادية والمحسنة.

JOESE 5

THE USE OF THE WASTAGE CRUMB RUBBER IN ROADS CONSTRUCTION

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Reprint

from

Journal of Environmental Sciences, 2010; Vol. 39, No. 4

http://www.mans.edu.eg/facscim/english/MJI **ISSN 1110-192X**